Geographic Information Systems

UNDERSTANDING GIS

What is GIS????

WHAT IS GIS?

Geographic Information Systems

Definition: A computer-based tool for mapping & analyzing geographic phenomenon.

Major Advantage: Combines database analysis capabilities with visualization of geographic data.

GIS Can: Integrate varying sources of information and help in making decisions by:

- Explaining events
- Predicting outcomes
- Planning strategies

Overall, GIS should be viewed as a technology, not simply as a computer system.

GIS Fully Defined:

A geographic information system (GIS) is a computer-based tool for mapping and analyzing geographic phenomenon that exist, and events that occur, on Earth.

"A geographic information system (GIS) is an information system that is designed to work with data referenced by spatial or geographic coordinates. In other words, a GIS is both a database system with specific capabilities for spatially-referenced data, as well as a set of operations for working with data. In a sense, a GIS may be thought of as a higher-order map."

A Comprehensive GIS technology integrates:

- common database operations such as query & statistical analysis
- visualization and geographic analysis benefits offered by maps
- ability to analyze aerial photographs and satellite images
- creation of statistical models

These abilities distinguish GIS from other information systems and make it valuable for explaining events, predicting outcomes, and planning strategies.

What Makes up a GIS?

By breaking down the phrase into its separate components,
Geographic
Information &
System,
we can get a better understanding of what really makes up a GIS.

Geographic

Information

Systems

Geographic

Spatial Data

Data that can be linked to a location on the earth or in space.

Examples:		
	Well locations	Soils
	Field Boundaries	Roads
	Streams	Wetlands
	Hydrologic Unit Data	County Boundaries
	Digital Elevation Models (DEM's)	
	Satellite Images	

Information

Tabular/Attribute Data

Data that describes data. Information about the spatial data.

Examples:

Wells Attribute Data:

Depth to Water	Nitrate Level
GPM	Municipal/Private Well
Year tested	Capped

Field Boundary Attribute Data:

Producer	Cropped / Not
Crop Type	Irrigated / Not
Acres	Program(s)

Soils Attribute Data:

Soil Type	Leaching Potential
Depth to Water	HEL / Non HEL

Systems

Data, Hardware, Software, People, Methods

The Geographic Information *System* is composed of several components. You can not have a GIS without any one of these items:

Data

Hardware

Software

People

Methods

GIS Components

Data

Possibly the most important component of a GIS is the data. Geographic data and related tabular data can be collected in-house or purchased from a commercial data provider. Without data, you have nothing to analyze.

Hardware

Hardware is the computer on which a GIS operates. Without hardware, you have no place to create, store, retrieve or output your data.

Software

GIS software provides the functions and tools needed to store, analyze, and display geographic information. Without software, there is no way to analyze data.

GIS Components

People

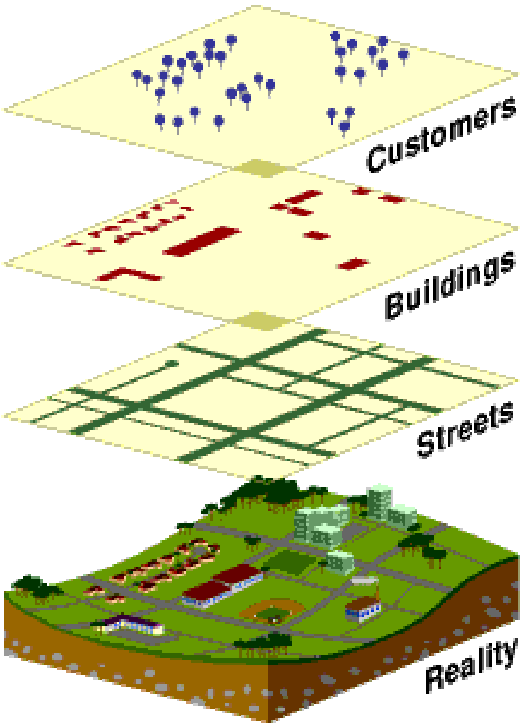
GIS technology is of limited value without the people who manage the system and develop plans for applying it to real-world problems. Without people, there is no way to run the system, maintain the data, or provide analysis to the end users.

Methods

A successful GIS operates according to a well-designed plan and business rules, which are the models and operating practices unique to each organization.

It is simply not sufficient for an organization to purchase a computer with some GIS software, hire some enthusiastic individuals and expect instant success.

Keep in mind, that the major aspect that makes a GIS different from a database management system (DBMS) is the link to geographic data. Being able to link information (attribute data) to a location on the earth's surface, allows us to produce analysis based on several different features at that location.



Maps & GIS


Federal "Wild Lands"


Software
Hardware
Data
GIS
People
Methods

Before GIS we had maps

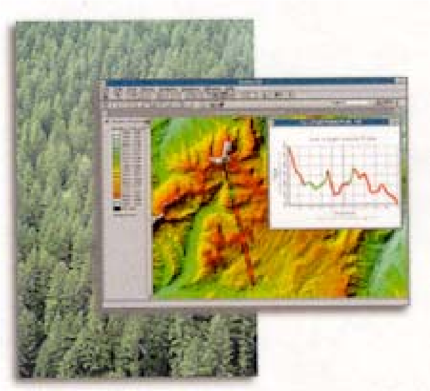
12th Century map of the Mediterranean

What Are Maps?

Maps are tools that provide us with information about the world in which we live. Maps have three principle uses:

- To **locate** places on the surface of the earth
- To show **patterns of distribution** of natural and man-made features
- To **compare** and **contrast** map information and thereby discover relationships between different phenomena

A MAP IS A MODEL OF THE REAL WORLD



Maps are the traditional method of storing & displaying geographic information

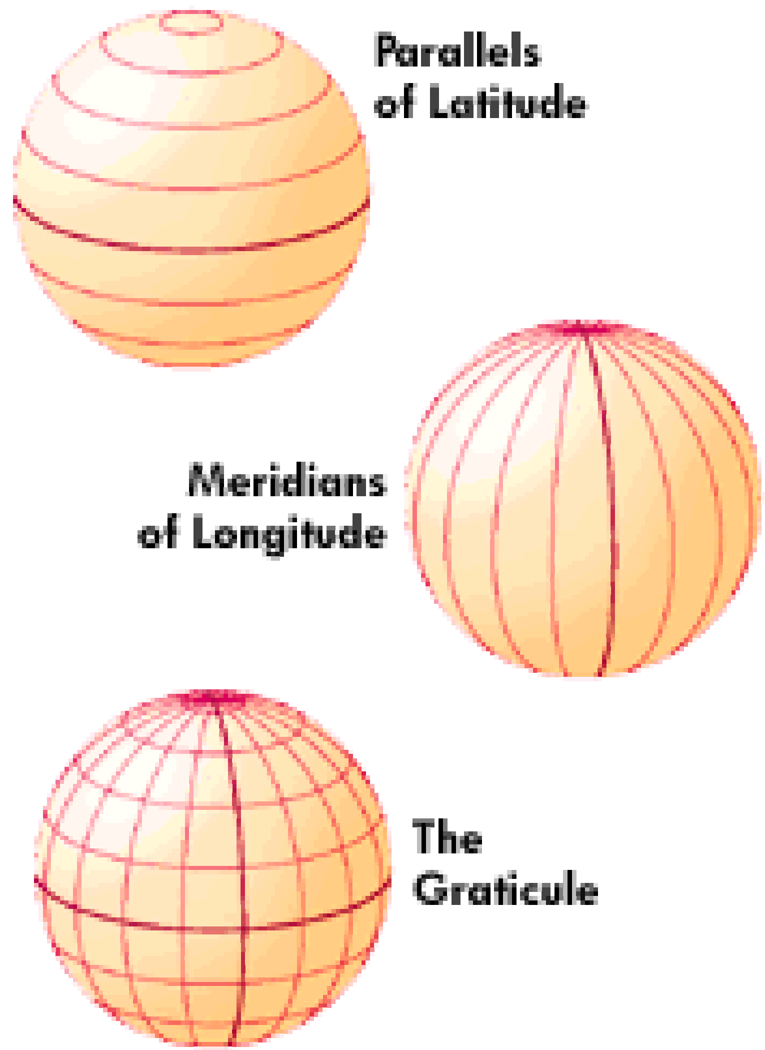
A map portrays three kinds of information about geographic features:

- Location & extent of the feature
  - Identified explicitly by reference to a coordinate system (UTM)
  - This is **Where** a feature is
- Attributes (characteristics) of the feature
  - Describe or characterize the feature
  - This is **What** the feature is
- Relationship of the feature to other features
  - Based on location & attributes of all features
  - This is **How** or **Why** a feature is

The identification of relationships between features, within a common map layer or across different map layers, is the primary function of a GIS

<u>Where</u> are features?
Latitude and Longitude

Latitude and longitude form a geographical coordinate system used for locating places on the surface of the earth. They are angular measurements, expressed as degrees of a circle measured from the center of the earth. The earth spins on its axis, which intersects the surface at the north and south poles. The poles are the natural starting place for the graticule, a spherical grid of latitude and longitude lines.

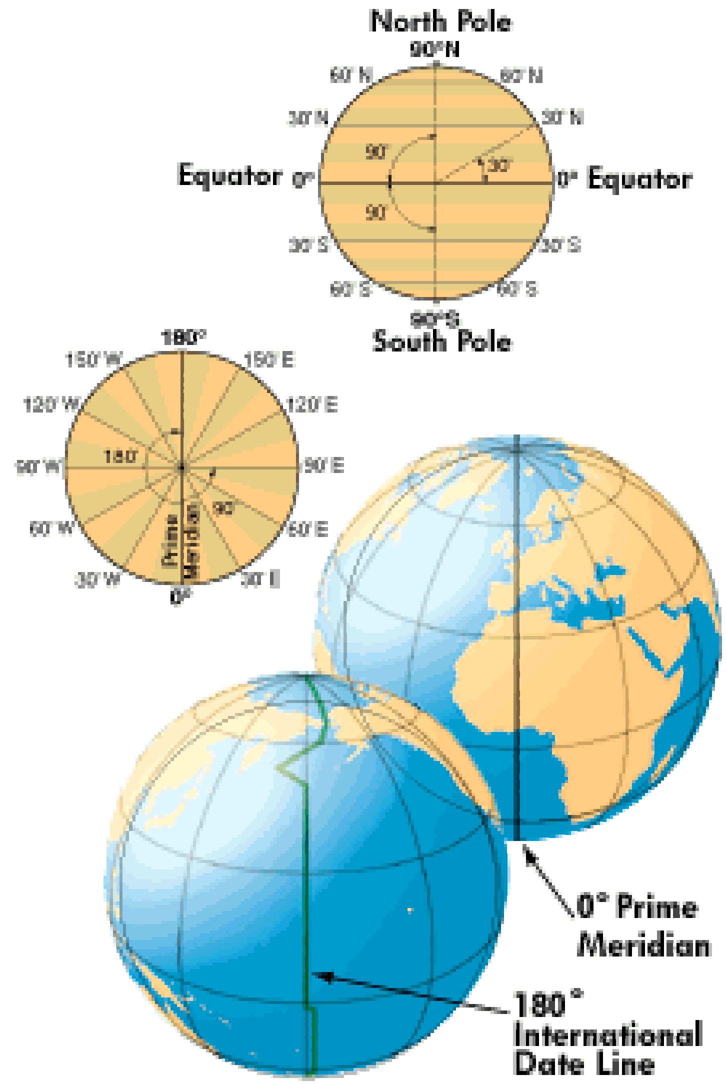


LATITUDE

Halfway between the poles lies the equator. Latitude is the angular measurement of a place expressed in degrees north or south of the equator. Latitude runs from 0° at the equator to 90°N or 90°S at the poles.

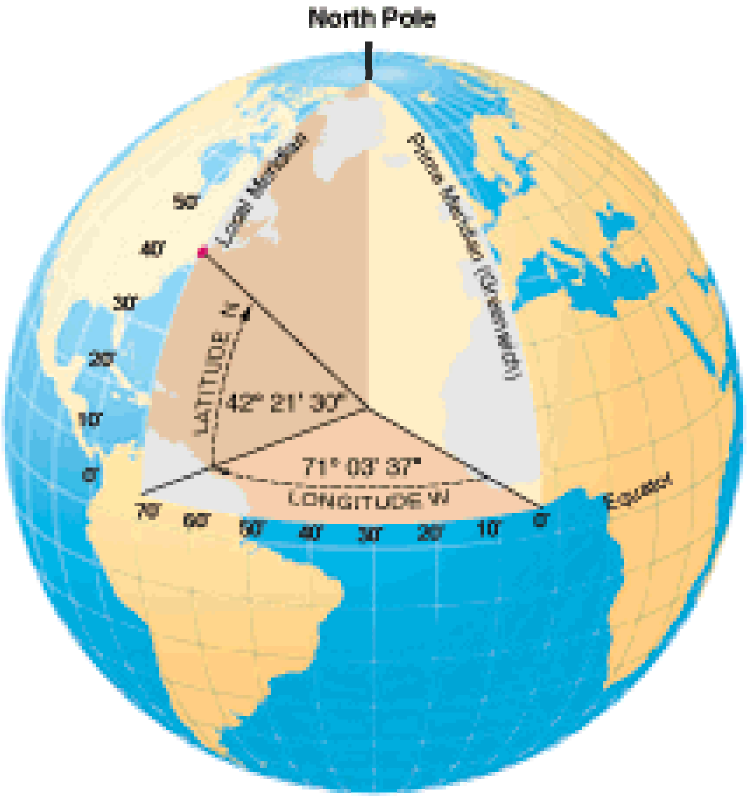
LONGITUDE

Lines of longitude, called meridians, run in a north-south direction from pole to pole. Longitude is the angular measurement of a place east or west of the prime meridian. Longitude runs from 0° at the prime meridian to 180° east or west, halfway around the globe.



How are latitude and longitude measured?

DEGREES, MINUTES, SECONDS



•A degree (°) of latitude or longitude can be subdivided into 60 parts called minutes (').

•Each minute can be further subdivided into 60 seconds (").

•One degree of latitude equals approximately 69 miles (111 km).

•One degree of longitude varies, from 69 miles at the equator to 0 at the poles because meridians converge at the poles.

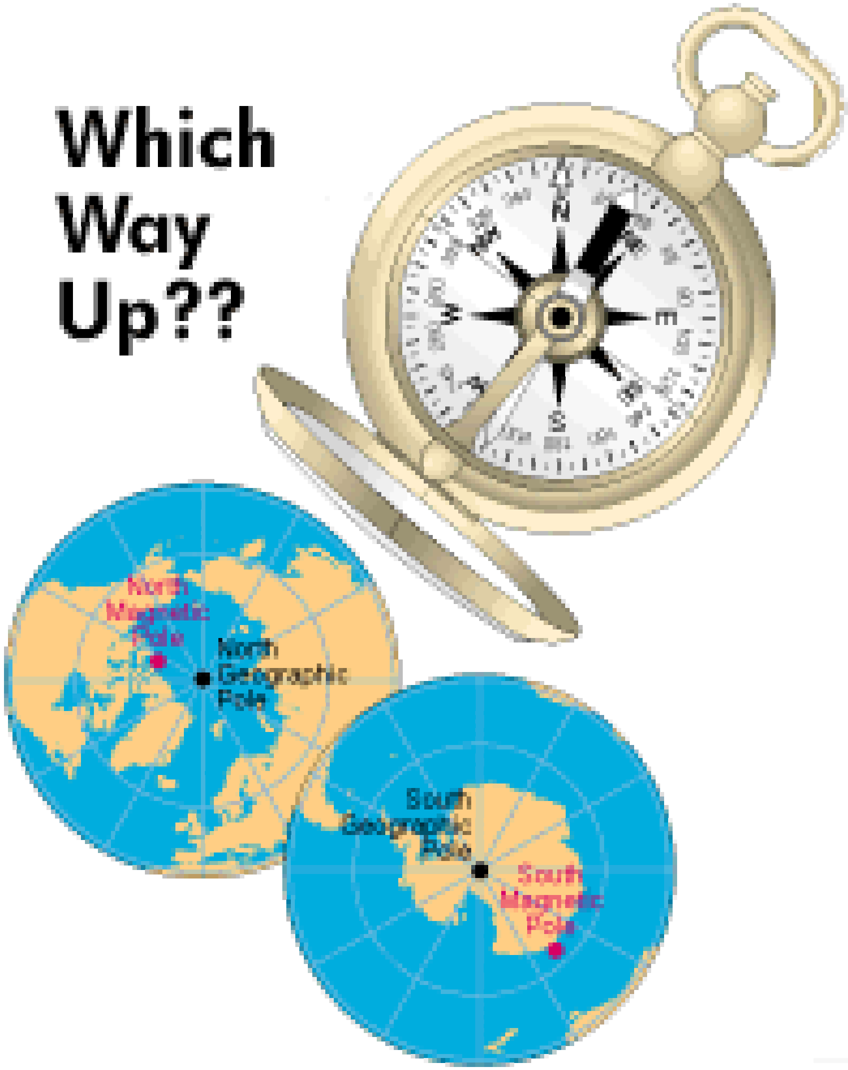
An example of Boston, Massachusetts located to the nearest second. It is written as:
42°21'30"N 71°03'37"W

Which way up?

•The north and south poles are the earth's geographic poles, located at each end of its axis of rotation.

•All meridians meet at these poles.

•The compass needle points to either of the earth's two magnetic poles.

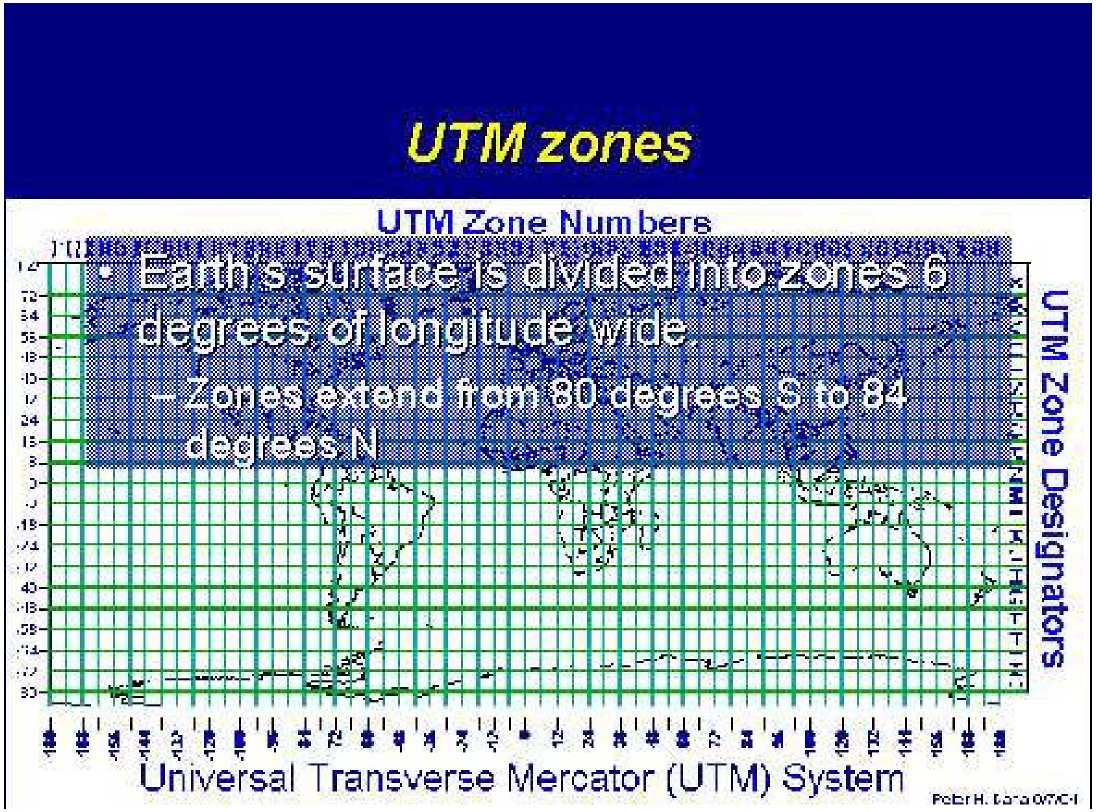


Universal Transverse Mercator (UTM)

• A series of 120 coordinate systems based on the Transverse Mercator projection.

• Sixty zones are used to map the northern hemisphere and the remaining 60 apply to the southern hemisphere.

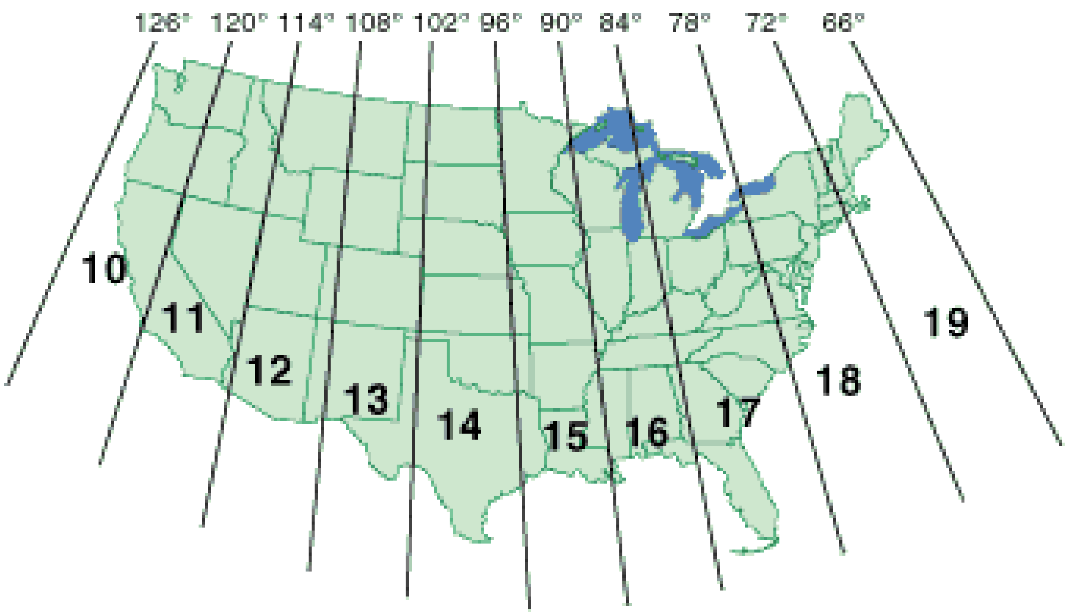
• Each zone is six degrees wide and is numbered.



Specifying Location in UTM

- All zones have their origin at the equator and use the meter as the system unit.
- North-South locations are measured from the equator referred to as a false northing of zero.
- East-West locations are measured from the Central Meridian.

The UTM system measurements are **ground measurements**, not angular and the units of measurement are **meters**, not degrees.



Map Scale

Scale can be defined as the relationship between distance on the map and distance on the ground.

Map Scale = Map Distance / Ground Distance

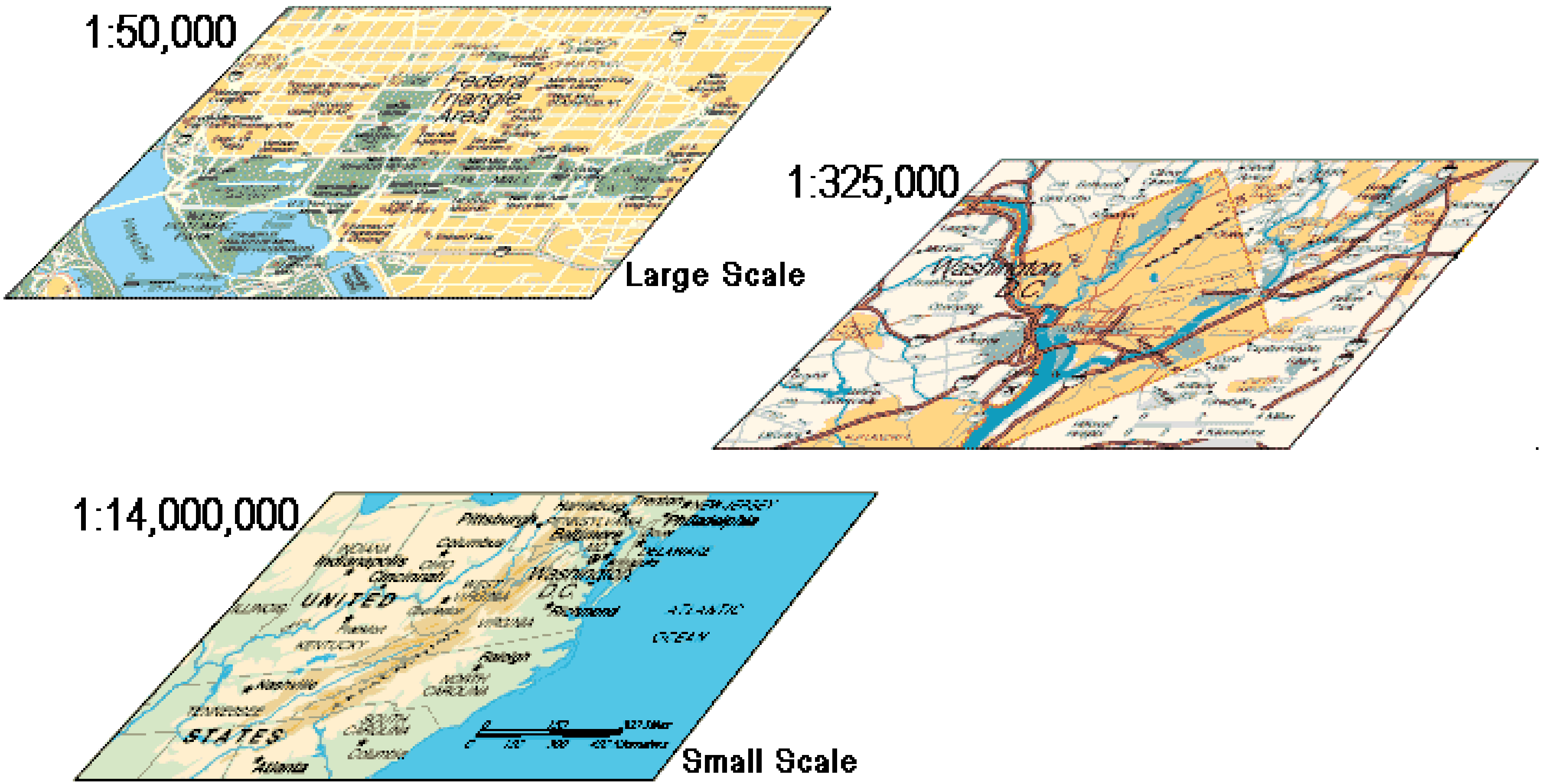
$$\text{Map Scale} = \frac{\text{Map Distance}}{\text{Ground Distance}}$$

Scales can be represented several ways:

- A **visual scale** (or bar scale) graphically shows the relationship between map distance and ground distance.
- A *numerical ratio* of map distance to ground distance, is called a **Representative Fraction.** It is usually written as 1/50,000 or 1:50,000, meaning that one unit of measurement on the map represents 50,000 of the same units on the ground.

Changing Scales
Large is Small?

The maps shown here show the effects of scale changes moving "closer to" or "farther from" the earth. A **large** scale map shows a small area with a large amount of detail. A **small** scale map shows a large area with a small amount of detail.



Map Projections

The only true representation of the earth, free of distortion, is a globe. Maps are flat, and the process by which geographic locations are transformed from a three-dimensional sphere to a two-dimensional flat map is called a projection.

Every map projection distorts at least three, and sometimes all four, of the following properties:

Shape

Area

Distance

Direction

Map Projections

To better understand what happens during the projection process, imagine the earth as a large inflated balloon.

Cut it apart, and flatten it to make a map. It will be stretched in some places, shrunk in others. Think of where and how the original balloon has been distorted.

CLASSIFICATION OF PROJECTIONS

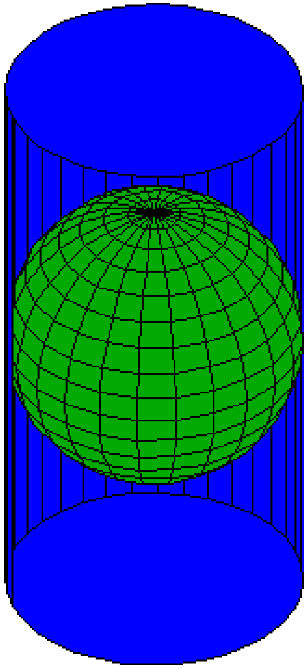
One method of classifying map projections is to group them by the type of surface onto which the globe is theoretically being projected:

- **Cylindrical**
- **Conic**
- **Azimuthal (Planar)**

Where the projection surface touches (is tangent to) the globe, scale is true. This can be at a point, or along one or two lines (called standard lines, or, if along a line of latitude, standard parallels). Distortion increases with increasing distance from the standard point or lines.

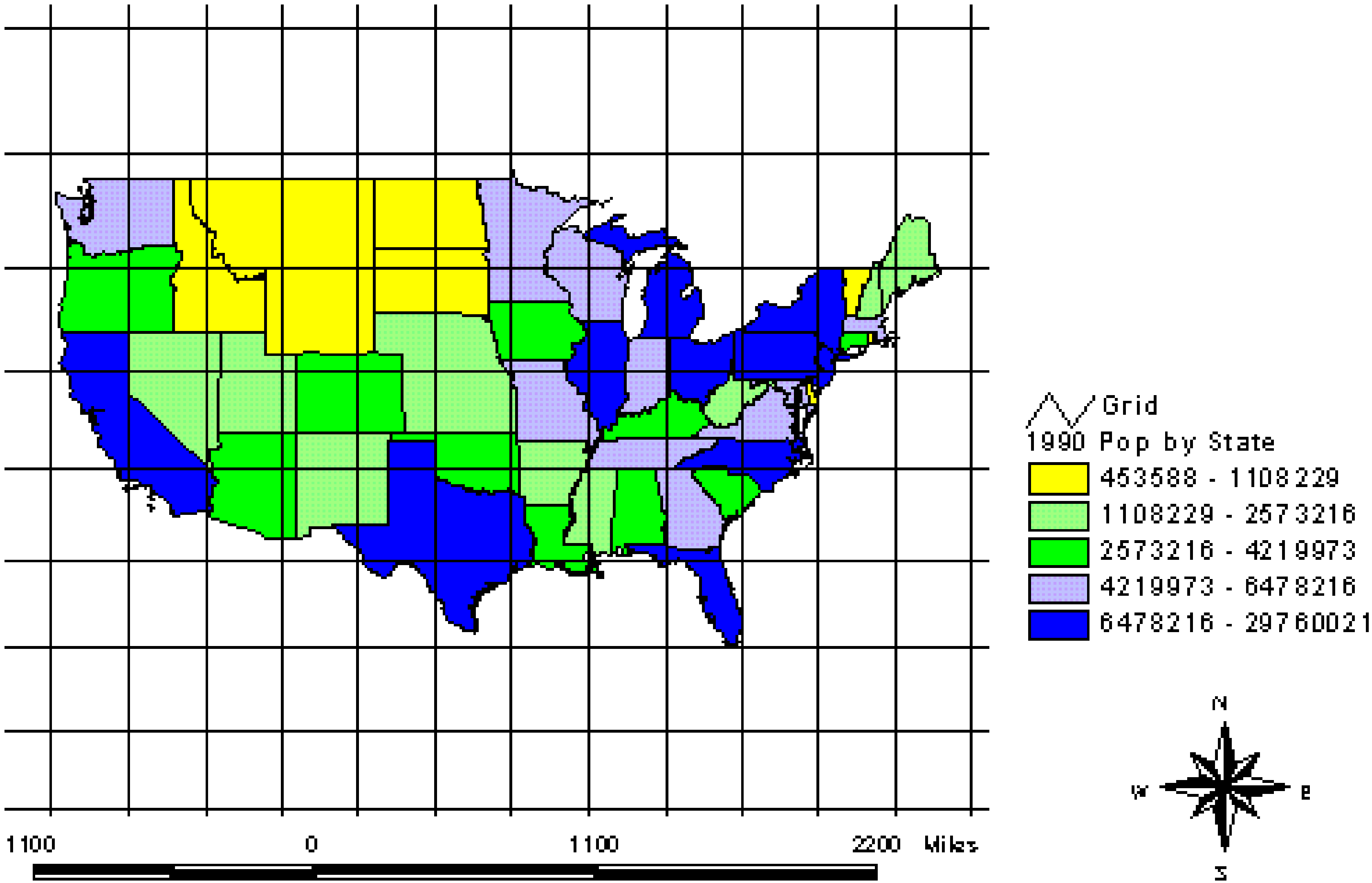
CYLINDRICAL

Imagine a light bulb in the center of a globe, with a sheet of paper wrapped around it in the form of a cylinder. Meridians and parallels would be "projected" onto the cylinder as straight, parallel lines. Because meridians on these projections do not meet at the poles, as they do on the globe, these maps are increasingly stretched and distorted toward the poles.



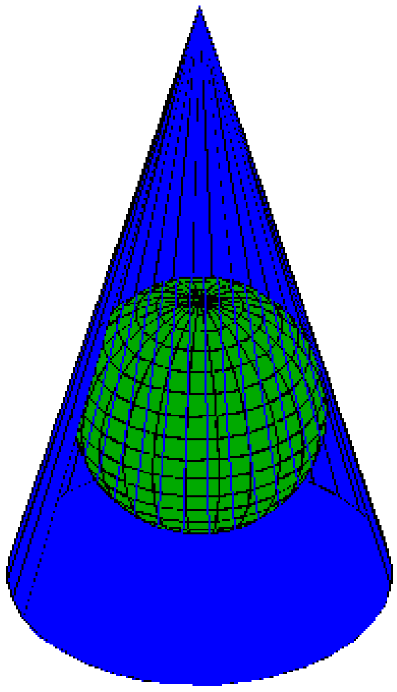
Cylindrical Projection Surface

Mercator Projection



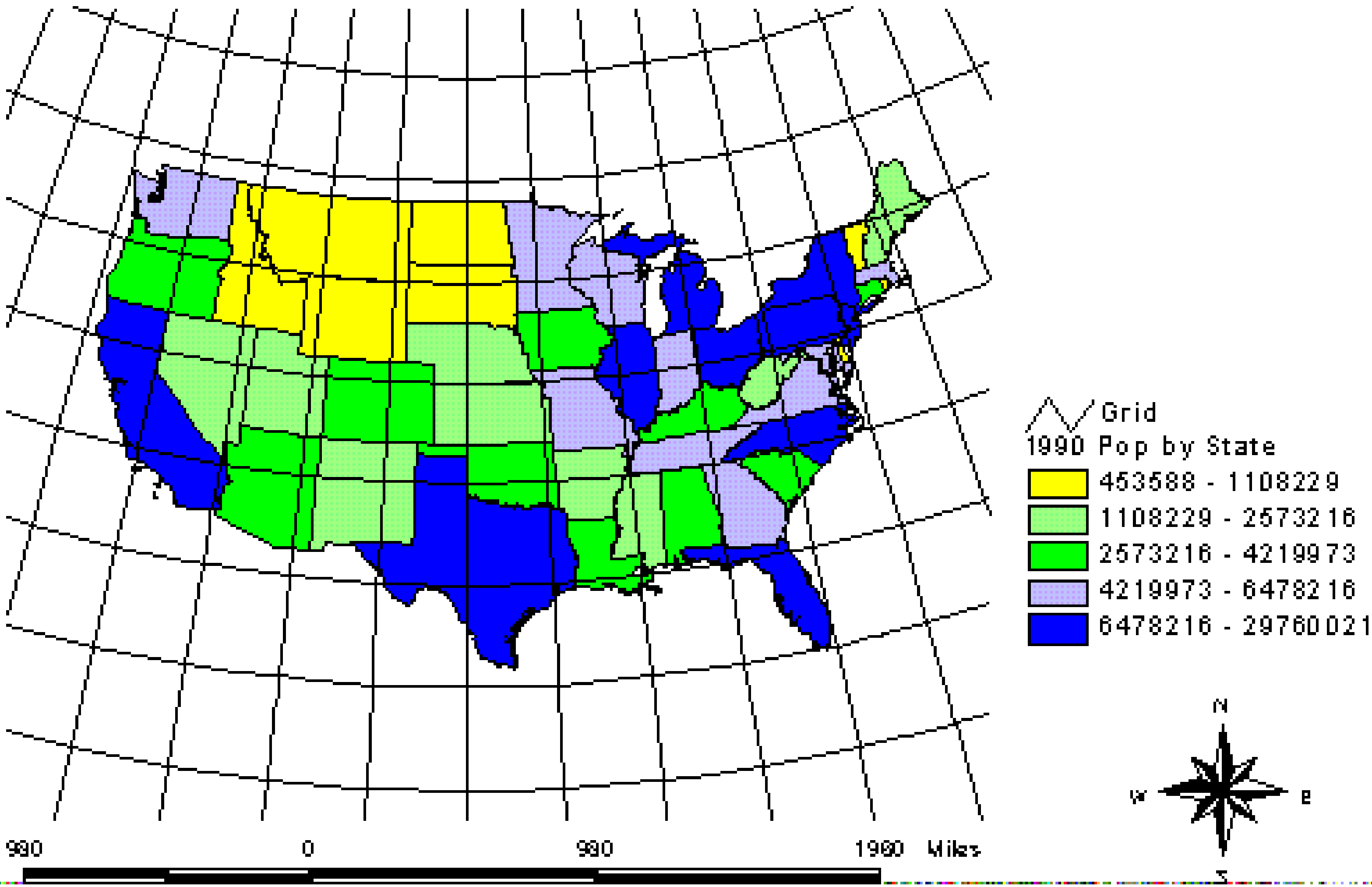
Conic Projection

A projection based on the geometry of the cone. The plain conic touches the earth at a specific parallel referred to as the Standard Parallel. A cone that sliced through the globe would intersect it twice, creating two standard parallels. Such a projection is well-suited for showing areas in the middle-latitudes with a mostly east-west extent (like the United States).



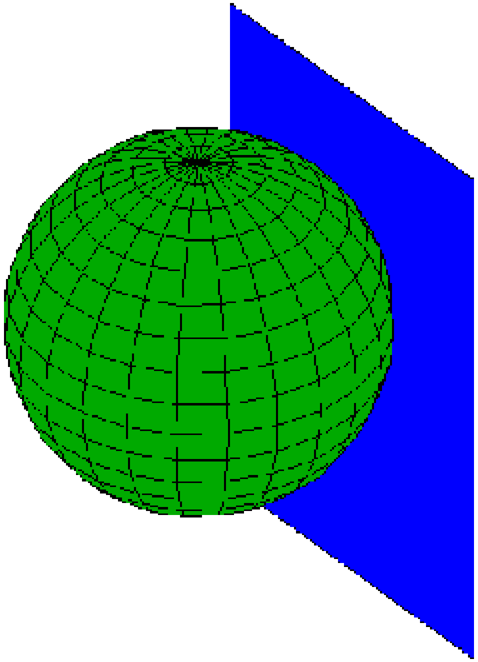
Conical Projection Surface

Lambert Conformal Conic Projection



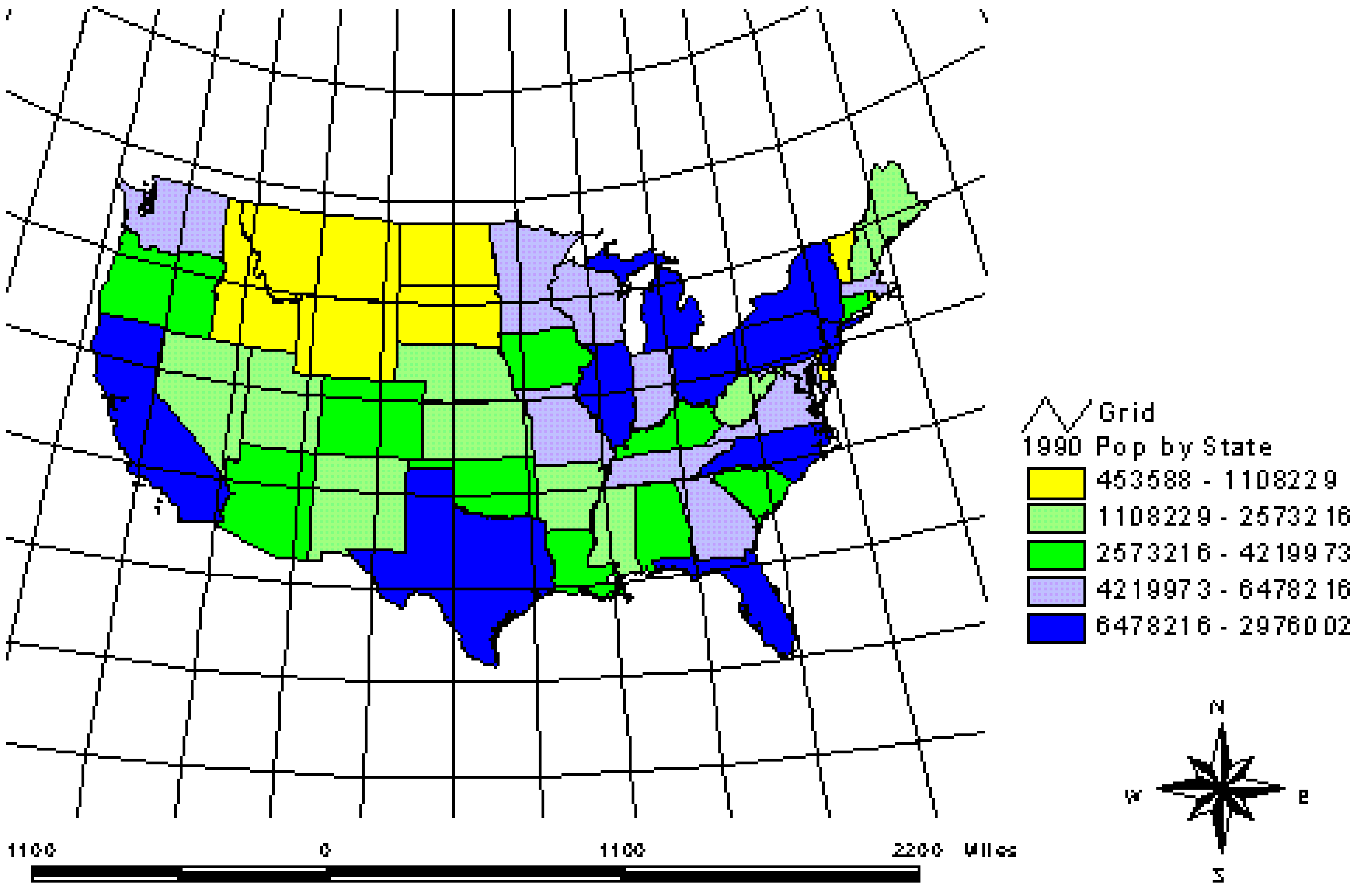
Azimuthal (Planar) Projection

A perfectly flat piece of paper (a plane) would touch the globe at a point. An azimuthal projection preserves the azimuth (distance) between certain objects. This projection is a good choice for maps with circular or square shapes.



Planar Projection Surface

Gnomonic Projection



When dealing with a GIS, we are trying to integrate the information that traditional maps have given us into a digital environment.

How does this happen?

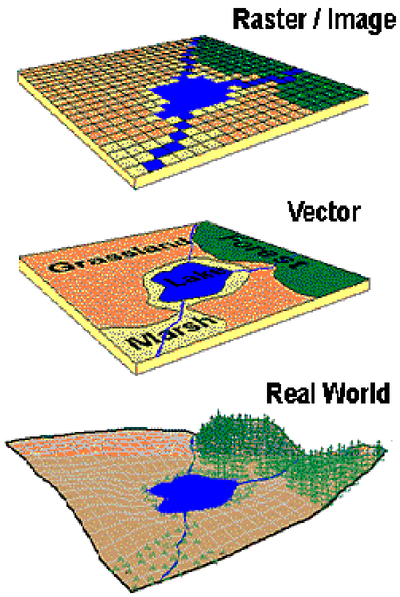
Traditionally spatial data has been stored and presented in the form of a map.

How can a GIS use the information in a map?

If the data to be used are not already in **digital** form, that is, in a form the computer can recognize, various techniques can be used to capture the information.

Two basic data formats were created to store data digitally:

- Vector
- Raster / Image



Data Modeling In GIS

Vector

and

Raster

Formats

Vector Model

• A coordinate-based data structure commonly used to represent linear geographic features.

• Each linear feature is represented as an ordered list of x,y coordinates or vertices.

• Vector Models give us information about points, lines and polygons.

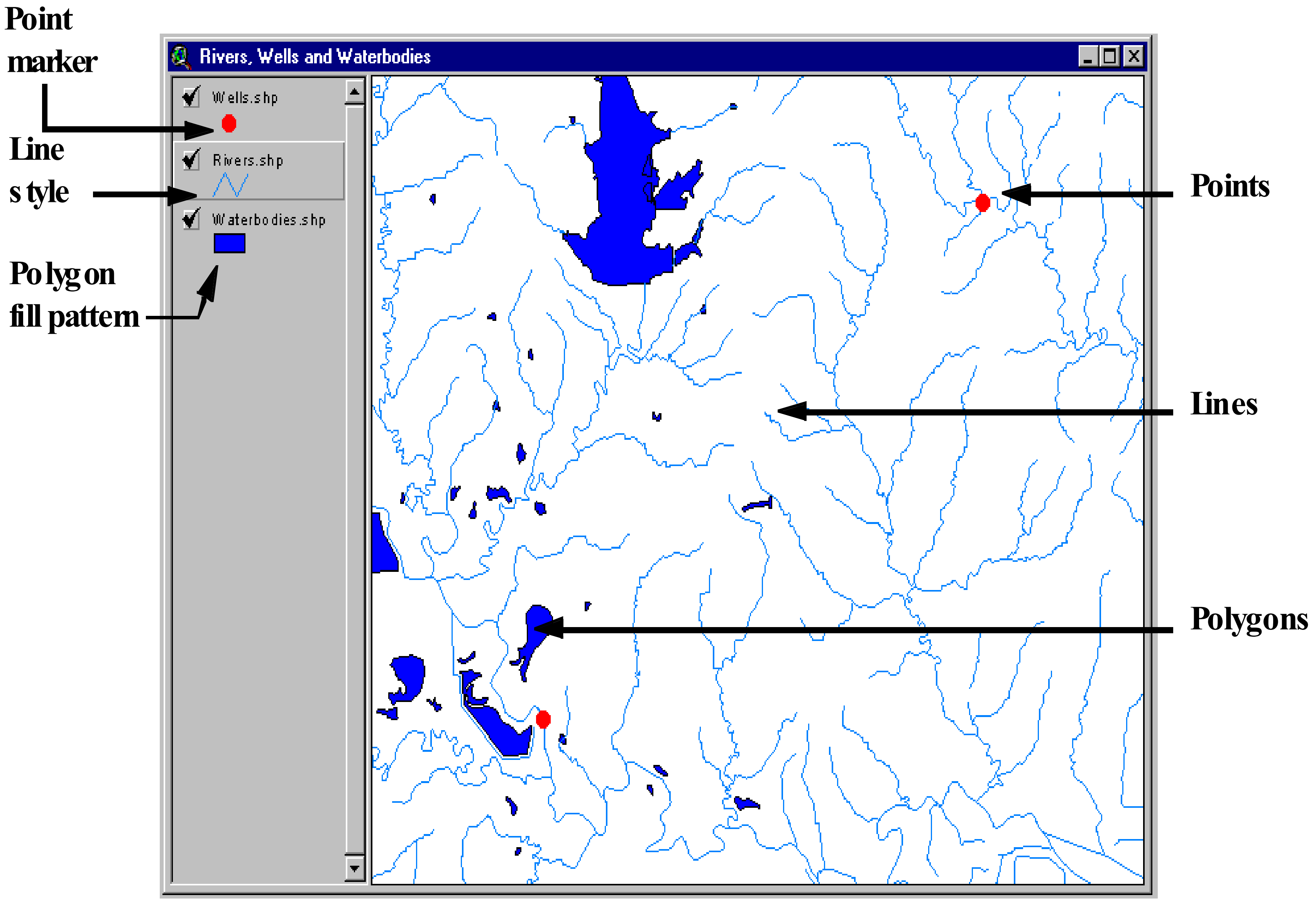
What are points, lines and areas?

Points - are identified as a single x,y coordinate that represents a geographic feature too small to be displayed as a line or area; for example, the location of a weather station or a well.

Lines - a set of ordered coordinates that represents linear features with no area (e.g., state and county boundary lines) or the shape of geographic features too narrow to be displayed as an area at a given scale (e.g., contours, street centerlines, or streams)

Polygons (Areas) - a feature described by a closed string of x,y coordinates. A polygon is defined by the lines that make up its boundary It is the most common type of data in natural resource applications. Examples include soil classification areas, administrative boundaries, and field boundaries.

Vector Data Example



How do you get data into a vector format?

Maps can be **digitized**, or hand-traced with at computer mouse, to collect the coordinates of features.

A digitizer is a device that consists of a table and a cursor with crosshairs and keys used to digitize geographic features.

The process of digitizing encodes the locations of geographic features by converting their map positions to a series of x,y coordinates stored in computer files. Pushing a digitizer button records an x,y coordinate. A digitized line is created by recording a series of x,y coordinates.

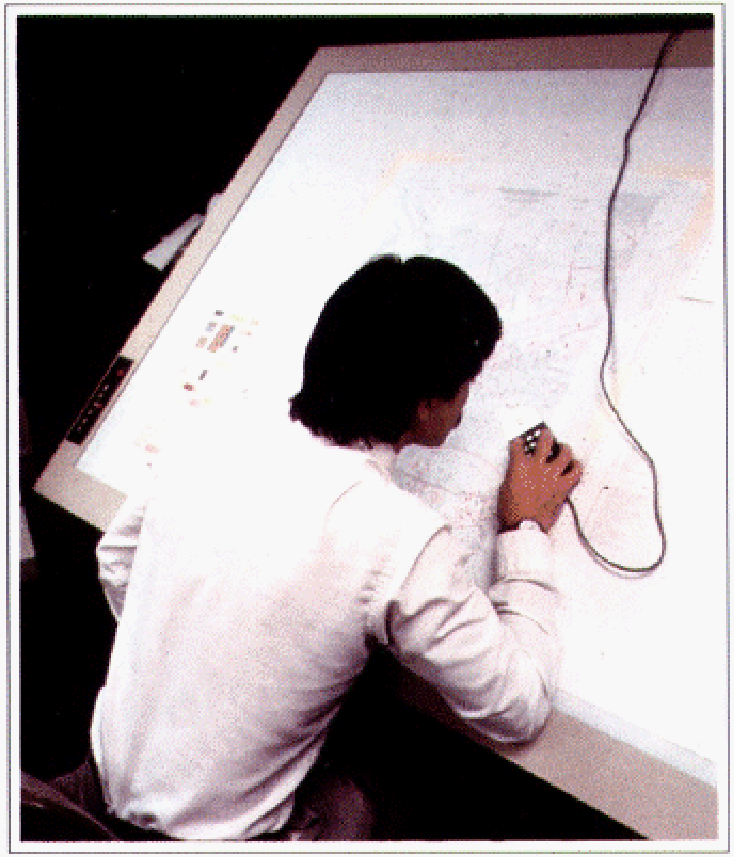


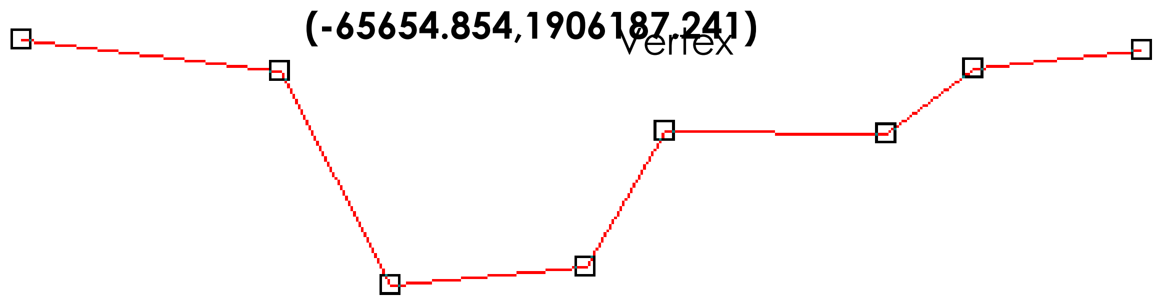
Figure 7. Converting map information to digital form using a hand-held computer mouse.

Point Data
X, Y Coordinate Pair

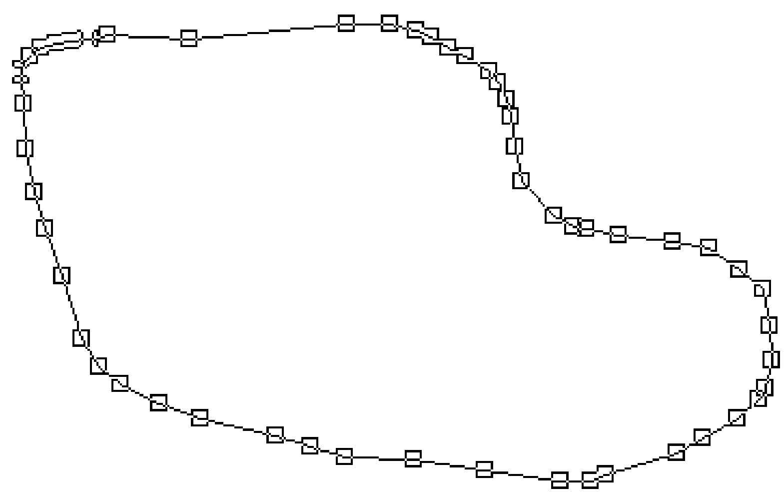
(-65654.854,1906187.241)

Node

Line or Vector Data



Polygon Data



Raster Model

• A geographic data model representing information in the form of a regular array of cells.

• The geographic area is divided into equally sized cells identified by row and column.

• Each grid cell is referenced by its geographic x,y location.

• Groups of cells with the same value represent features.

Raster Terminology

image - A graphic representation or description of a scene, typically produced by an optical or electronic device. Common examples include remotely sensed data (e.g., satellite data), scanned data, and photographs.

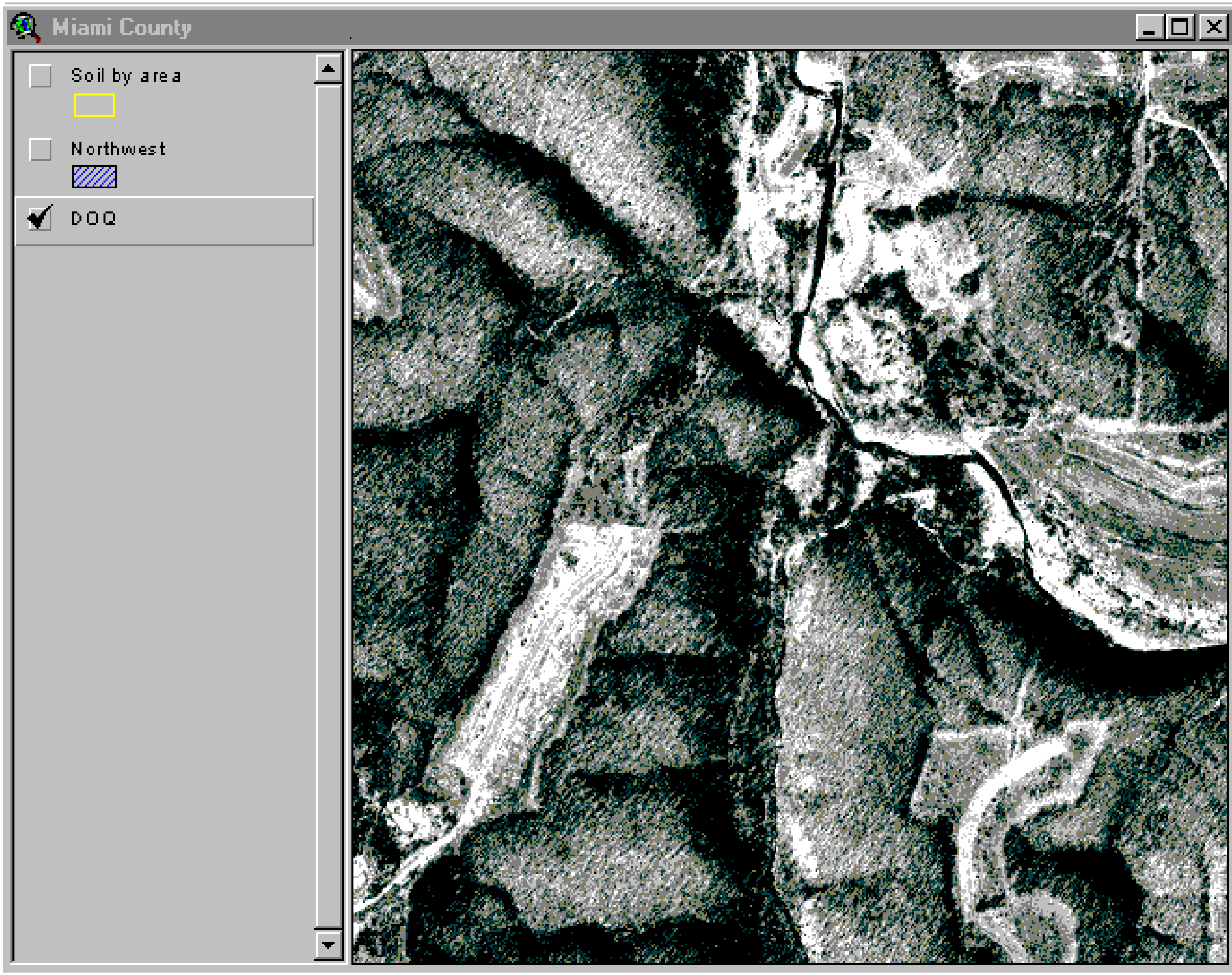
pixel - A contraction of the words picture element. The smallest unit of information in an image or raster map. Referred to as a cell in an image or grid.

bitmap - defines a display space and the color for each pixel or "bit" in the display space.

remote sensing -acquiring information about an object without contacting it physically. Methods include aerial photography, radar, and satellite imaging.

Examples of raster image file types are: **BMP**, **TIFF**, **GIF**, and **JPEG** files.

Raster Data Example



How do you get data in a raster format?

Raster graphics are digital images created or captured as a set of samples of a given space. Electronic scanning devices convert map lines and points to digits for computer editing and display. Some scanners also use software to convert raster data to vector data.

A GIS can also convert existing digital information, which may not yet be in map form, into forms it can recognize and use. For exam ple, digital satellite images or aerial photographs can be analyzed to produce a map- like layer of digital information about vegetative covers.

Figure 8. An electronic scanning device will convert some types of map information to digital form.

Vector vs. Raster Format

Pros and Cons

• A raster/image file is usually larger than a vector format file.

• A raster file is usually difficult to modify without loss of information, although there are software tools that can convert a raster file into a vector file for refinement and changes.

• Vector format data is designed to be quickly rescaled.

What is GPS?

The *global positioning system* is a satellite-based navigation system consisting of a network of 24 orbiting satellites making it possible for people with ground receivers to pinpoint their geographic location.

The satellites are constantly moving, making two complete orbits around the Earth in just under 24 hours. The orbital paths of these satellites take them between roughly 60 degrees North and 60 degrees South latitudes, enabling the reception of satellite signals anywhere in the world, at any time.

To determine your position the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received by the GPS receiver. The time difference tells the GPS receiver how far away that particular satellite is.

Briefly, here's how GPS works:

• Each satellite contains a computer, an atomic clock, and a radio. With an understanding of its own orbit and the clock, it continually broadcasts its changing position and time.

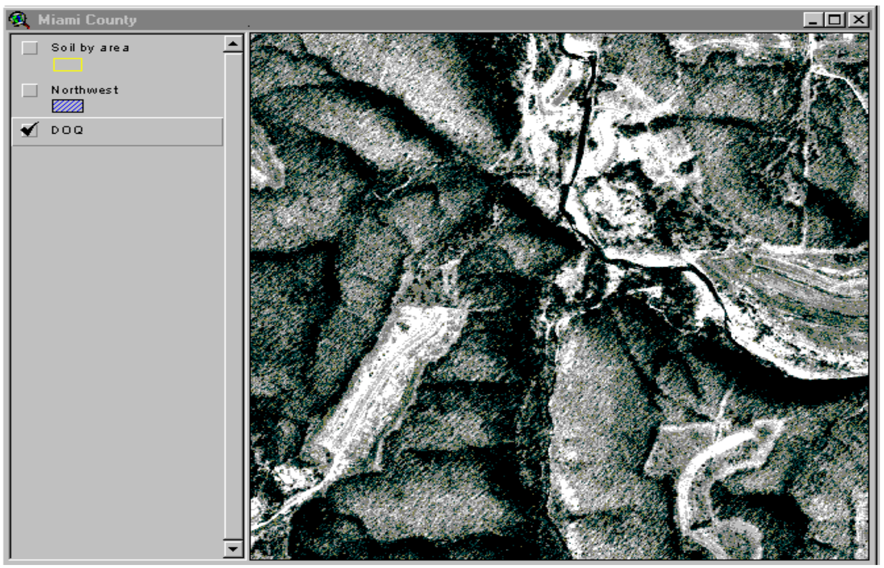
• On the ground, any GPS receiver contains a computer that "triangulates" its own position by getting bearings from three of the four satellites. The result is provided in the form of a geographic position - longitude and latitude - accurate to, for most receivers, within 100 meters.

• If the receiver is also equipped with a display screen that shows a map, the position can be shown on the map.

• If a fourth satellite can be received, the receiver/computer can figure out the altitude as well as the geographic position.

• If you are moving, your receiver may also be able to calculate your speed and direction of travel and give you estimated times of arrival to specified destinations.

How is all of this relevant to USDA?



GIS for Agricultural Production

Today's farmer has a new set of technological tools that include global positioning system (GPS) receivers, satellite imagery, aerial photography and laptop computers. GIS software can help you integrate data and use these tools in a variety of precision agriculture applications to record and analyze agronomy variables, obtain information on crops and soils, and help make decisions on where to apply chemicals or pesticides.

A GIS can query the relationship among agronomic variables such as nutrient values and moisture levels to create fertilizer prescription contour maps that are used with variable rate application field equipment to improve yields and increase profits.

GIS for Agribusiness

Agribusiness relies on geographic or locational information for tasks such as food processing, transportation, marketing, and agricultural production.

- Agriculture retailers use GIS to market and efficiently transport fertilizers and ag chemicals to growers.

- Agricultural lenders and crop insurance firms use GIS software to rate and market crop insurance policies.

- Agribusiness wholesale trade and transport organizations can lower costs by using GIS to calculate efficient truck, rail, and shipping routes for distribution of their products.

GIS in Education

Agriculture schools at Land Grant universities are creating many of today's leading agriculture production applications.

Throughout the U.S. and its territories, there are 130 colleges of agriculture participating in the Land Grant program, as well as 59 agriculture experiment stations, 57 cooperative extension services, and 63 schools of forestry.

They are carrying out thousands of projects in agronomy, soil science, crop science, entomology, weed science, botany, biochemistry, agricultural engineering, and agriculture economics.